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RAPESEED MEAL AS A PROTEIN SOURCE FOR SWINE REPRODUCTION

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Rapeseed Meal as a Protein Source for Swine Reproduction" submitted by Frederick William Schuld, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Experiments were designed to study the effects on growth, reproduction and lactation and on growth of progeny when 8% solvent-extracted rapeseed meal was substituted for an isonitrogenous level of soybean meal in the diets. Two experiments were conducted: one with sows and one with their offspring. Experiment 1, using 24 sows, was factorially designed with 2 levels of dietary rapeseed meal (0 and 8%) to 90 kg liveweight with each lot further subdivided between 0 and 8% rapeseed meal for reproduction. In experiment 2, offspring of both sexes from the dams receiving either 0 or 8% rapeseed meal were allotted to either 0 or 8% rapeseed meal diets from weaning to market weight.

Feeding rapeseed meal to gilts tended to depress rate of gain in the period from 55 to 90 kg liveweight and in the pre-gestation period. Weaning weights of litters from sows fed rapeseed meal during growth were depressed. The fat content of colostrum was higher in sows fed rapeseed meal during growth. The increased fat content was reflected in a rise in total solids content of the colostrum. The fatty acid composition of the colostral and milk fat was not affected by dietary treatments. The feeding of rapeseed meal during gestation and lactation had no significant effects on sow or litter performance.

In experiment 2, the feeding of rapeseed meal led to a depression in feed consumption and in gain in the finishing period from 55 to 90 kg liveweight and a depression in efficiency of feed utilization from weaning to market weight. No differences were observed in the digestibility and retention of energy and nitrogen of pigs fed either the basal soybean meal diets or the rapeseed meal diets. The carcasses of pigs fed rapeseed meal were leaner based on reduced backfat depth, increased ham weight as a percent of carcass weight and a trend toward higher Record of Performance scores.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Rapeseed is an important crop in Western Canada. Production of 22.8 million bushels of rapeseed in 1965 was almost double the 1964 production of 13.2 million bushels. The 1966 crop is estimated to be similar to that of 1965. Almost 50% of the crop is exported as whole rapeseed. The remainder is chiefly for production of edible oils for domestic consumption.

Rapeseed meal is a high protein by-product of oil extraction and a potential substitute for soybean meal and other vegetable protein meals in livestock and poultry diets. Its use in feeds, especially starting and breeding swine diets, has been limited by regulation. Recent changes in processing methods have made rapeseed meal more attractive as a protein supplement and have resulted in removal in 1966 of the restrictive ruling of the Feeds Act.

Two species of rapeseed are grown in Western Canada: *Brassica napus* L., commonly called Argentine rapeseed and *Brassica campestris* L., commonly called Polish rapeseed. The Polish type usually has a lower protein and oxazolidinethione content than the Argentine type. Oxazolidinethione and other compounds in rapeseed inhibit thyroid function, and therefore may have adverse effects on growth.

Research information is limited on the use of rapeseed meal in swine reproduction diets. Therefore, studies were undertaken to determine the effects of including solvent-extracted rapeseed meal in swine diets on growth of female breeding stock, on their reproductive and lactational performance and on the performance of their offspring.

REVIEW OF LITERATURE

Bell (1955), in a review article, stated that published German experiments on the nutritive value of rapeseed meal go back to 1872. He also stated that the first North American report on this subject appeared in 1944. Today the use of rapeseed meal as a protein supplement in swine diets is not as extensive as it might be when quality, availability and price are taken into consideration. Reluctance to use rapeseed meal in some livestock diets stems from reports of adverse effects on growth and reproduction associated with undesirable principles in rapeseed meal. A recent review (Bowland, Clandinin and Wetter, 1965) discusses the nutritive value of rapeseed meal, and shows that a much better quality product is being produced today than 10 to 15 years ago.

A. Goitrogenic Properties of Rapeseed Meal

1. Nature of the potentially toxic factors

Chesney, Clawson and Webster in 1928 first observed the presence of goitrogens in food, when experimental rabbits on a fresh cabbage diet showed up to 200-fold thyroid enlargement. Kennedy and Purves (1941) first reported that rapeseed had goitrogenic properties. Rapeseed and mustard seed were known to be rich in glucosides, and when these seeds were fed to rats, goiters were produced. After feeding rapeseed meal for 3 weeks, thyroid enlargement reached a plateau, although after 9 weeks on rapeseed meal the thyroid re-accumulated some colloid while retaining its hypertrophy. Similar results were obtained recently by Manns (1962) with rats and pigs and by Bowland and Standish (1966) with rats.

In rapeseed meal, thioglucosides are the chief undesirable principles. On enzymatic hydrolysis these glucosides give rise to mustard oils,

isothiocyanate and oxazolidinethione. Kjaer, Conti and Jensen (1953) began a series of investigations into the natural mustard oils and their thioglucoside precursors. The first thioglucoside isolated from plant sources was sinigrin from black mustard seed by Bussy in 1840 (cited by Bell and Belzile, 1965), which when treated with the enzyme myrosinase, produced allyl isothiocyanate. Sinalbin is a thioglucoside in rapeseed and gives rise to glucose and p-hydroxybenzyl isothiocyanate upon hydrolysis. Clandinin (1961) ascribes the sharp bitter taste of rapeseed to this isothiocyanate.

Myrosinase is an enzyme found in rapeseed. The enzyme was first isolated by Boutron and Fremy in 1840 (cited by Bell and Belzile, 1965) and called myrosin. Myrosinase may be obtained by extraction of Brassica seeds and the enzyme catalyzes the hydrolysis of mustard oil thioglucosides to isothiocyanates. Kjaer, Conti and Jensen (1953) isolated and identified three volatile mustard oils and found evidence for three major and three minor thioglucosides in rapeseed. Progoitrin and gluconapin are the major non-volatile thioglucosides. Astwood, Greer and Ettlinger (1949) and Carrol (1949) isolated and characterized (-)-5-vinyl-2-oxazolidinethione from rapeseed. This compound was found to be goitrogenic for rats and humans and was given the name goitrin. The glucoside precursor of goitrin was named progoitrin. Progoitrin, under the action of myrosinase (Pitt-Rivers, 1950), gives rise to 3-butenyl isothiocyanate which may give rise to goitrin by cyclization. Clandinin, Renner and Robblee (1959) found that heat increased the goitrogenicity of rapeseed meal by conversion of isothiocyanate to non-volatile goitrin.

2. Action of goitrogens

Rapeseed meal has been shown to be goitrogenic for various non-

ruminants. Pettit et al (1944) reported that 20% rapeseed meal in a chick starter diet caused thyroid hypertrophy. Clandinin and Bayly (1960) reported that 15% Polish or 5% Argentine type rapeseed meal doubled thyroid-to-body-weight ratios in chicks. Blakely and Anderson (1948a), feeding 20% rapeseed meal to turkey poults, demonstrated a five to six-fold increase in thyroid weight. Hussar and Bowland (1959a) and Manns et al (1963) observed reduced standard metabolic rates in rats fed 10% rapeseed meal. These two authors also showed that in swine, serum protein bound iodine (PBI) was reduced when rapeseed meal was fed from weaning to market weight. They demonstrated thyroid hypertrophy due to feeding of rapeseed meal. There is little evidence to show that rapeseed meal is goitrogenic for ruminants. For example, Bezeau et al (1960) reported no thyroid enlargement occurred in ewes fed rapeseed meal as 30% of their diet.

The feeding of iodide has been shown to partially correct goitrogenic effects of rapeseed meal (Bell and Belzile, 1965, Kratzer et al, 1954, Purves, 1943). Iodinated casein or thyroxine feeding have helped prevent goiters to some degree (Blakely and Anderson, 1948b, Kratzer et al, 1954, Purves, 1943). Kennedy and Purves (1941) showed that hypophysectomy prevented thyroid hypertrophy. Thyroxine, but not iodine or diiodotyrosine prevented hyperplasia due to rapeseed feeding in rats. Therefore, it appears that rapeseed goitrogens interfere with thyroxine synthesis, and that the anterior pituitary, producing thyroid stimulating hormone (TSH), causes thyroid hypertrophy and hyperplasia. Greer (1962) classified antithyroid compounds according to their modes of action. Oxazolidine-thione, apparently interferes with the organic binding of iodine, in which the most sensitive reaction is the coupling of two iodinated tyrosine molecules to form thyroxine or triiodothyronine, which are the thyroid

hormones. Iodination of tyrosine may also be impaired. Isothiocyanates that have significant antithyroid activities include only those capable of cyclizing to form oxazolidinethione. Greer (1962) stated that few antithyroid substances are capable of blocking thyroxine action once it has left the thyroid gland.

B. Nutritive Value of Rapeseed Meal

1. Effect of processing methods

Clandinin, Renner, and Robblee (1959) showed that high temperature processing of rapeseed meal in the expeller process led to a 25% reduction in lysine content of the protein of rapeseed meal. Clandinin and Tajcnar (1961) reported that the lysine content of expeller-processed meal varied from 3.69 to 5.37% of the protein and lysine level was positively correlated with percent fat, which varied from 5.2 to 9.7%. Less than 6% residual fat in expeller-processed meal was accompanied by a marked reduction of lysine content. Clandinin (1965) found an average of 5.5% lysine in protein of fifteen meals from prepress plus solvent process plants. Finlayson (1965) reported a lysine content of 6.6% of the protein in meal from a straight solvent-extraction plant.

Processing of rapeseed meal affects thioglucoside content by activation or deactivation of myrosinase and by chemical modification of thioglucosides. High temperatures and high moisture content lead to rapid hydrolysis of thioglucosides to isothiocyanates (Mustakas et al, 1962) Only solvent or prepress plus solvent extraction processes are used in Canada now, with the exception of one unit in Eastern Canada. These processes result in a meal which is myrosinase-free (Bell and Belzile, 1965) and which contains unhydrolyzed thioglucosides. Clandinin (1965) tested ten different meals at levels of 15% in chick diets. He reported

that chicks fed diets containing prepress-solvent and solvent-extracted rapeseed meals grew 94% and 94.5%, respectively, as rapidly as chicks on a soybean meal control diet.

2. Value in starting diets

In starting swine diets, acceptability and palatability of a diet are important to ensure adequate intake of feed. The sharp bitter taste of rapeseed meal (Clandinin, 1961) may result in decreased feed intake. Bowland (1957) observed that pigs did not accept a prestarter diet containing 2 to 10% rapeseed meal (expeller-extracted) when alternative diets were available. Manns (1962) observed no depression in feed intake when all the soybean meal in a 13% soybean meal diet was replaced isonitrogenously by Polish solvent-extracted rapeseed meal. Seale in 1952 (cited by Bowland, 1965a) showed that 13 to 26% rapeseed meal in diets for pigs from 18 to 36 kg body weight did not adversely affect feed consumption. Stothers in 1964, (cited by Bowland, 1965a) observed a depression of 20% in feed intake when rapeseed meal replaced all the soybean meal (10.4%) in diets for 14 kg pigs. In general, levels of 10% or less of rapeseed meal in pig starting diets appear not to affect intake.

Hussar and Bowland (1959a) observed that average daily gain was not significantly depressed in group-fed pigs from 6 to 16 kg liveweight when they were fed 2% or 10% expeller-extracted rapeseed meal in substitution for soybean meal. In individually-fed pigs, a 0.06 kg per day depression in gain was observed, although efficiency of feed utilization was not affected. Manns and Bowland (1963a) reported that if 25% of the soybean meal were replaced with solvent-extracted rapeseed meal, gain was not depressed, but at a substitution rate of 50% and 100%, gain

was depressed 0.07 and 0.10 kg per day, respectively, for group-fed pigs from 9 to 23 kg liveweight. Seale in 1952 (cited by Bowland, 1965a) showed that gain and feed efficiency were not affected by inclusion of rapeseed meal in starting diets. Stothers, in 1964 (cited by Bowland, 1965a), later showed that substitution in the diet of starting pigs of 50 or 100% of the soybean meal with rapeseed meal led to a reduced rate of gain but feed efficiency was not affected. In general, levels of 5% or less of rapeseed meal do not appear to affect gain and efficiency of feed utilization of pigs from three weeks of age to 25 kg liveweight, and levels of up to 10% may be acceptable.

3. Value in growing and finishing diets

Frölich and Haring (1937a) fed up to 200 gm daily of rapeseed meal to young growing pigs with satisfactory results, but they found that average daily gain was depressed in finishing pigs if more than 150 gm with low mustard oil content (0.11 to 0.13%) and more than 100 gm with high mustard oil content was fed. Cook (1941) observed that substitution of rapeseed meal for meat meal gave poor results with pigs. Seale in 1952 (cited by Bowland, 1965a) compared linseed meal and rapeseed meal in diets for swine from 36 kg to 91 kg liveweight. Pigs fed rapeseed meal made slower and less efficient gains although performance was not affected up to 36 kg liveweight by rapeseed meal. When rapeseed meal replaced only 50% of the linseed meal, gain and feed to gain ratios were comparable to those of pigs on linseed meal diets. Pigs fed rapeseed meal tended to waste feed and consumed feed more slowly than pigs fed linseed meal. Further studies by Seale in 1953 (cited by Bowland, 1965a) showed that in a 35% protein supplement containing 20% meat meal, 20% alfalfa meal and 60% linseed meal, rapeseed meal could replace

all the linseed meal without significantly affecting gain, feed intake and efficiency of feed utilization. Clausen, in Denmark (cited by Bowland, 1965a) observed a marked depression in feed consumption, rate of gain and feed efficiency when rapeseed meal was substituted for milk protein in the diets of 24 pigs started at 24 kg liveweight. Fevrier, in 1957 (cited by Bowland, 1965a) reported on experiments in which 10% to 25% rapeseed meal treated by the André process, involving heat and steam extraction, was fed to swine. Daily gain was lower on the highest level of rapeseed meal. Further steam treatment resulted in improved feed intake, average daily gain and feed efficiency. Hussar and Bowland (1959a) showed that 10%, but not 2%, expeller-extracted Argentine rapeseed meal depressed rate of gain and in some cases depressed feed utilization in growing and market pigs. Manns and Bowland (1963a), replacing 0, 25, 50 and 100% of the soybean meal in diets with rapeseed meal (levels up to 15.6% in growing and up 9.6% in finishing diets), reported that the 25% level did not influence average daily gain, average feed intake or feed efficiency, but at the 50 and 100% levels gain and feed efficiency were depressed in group-fed pigs from 23 to 50 kg liveweight. The addition of lysine at the high level of rapeseed meal feeding had no effect on gain and depressed feed efficiency. In general it appears that levels from 6 to 10% of solvent-extracted rapeseed meal are satisfactory in swine diets from 25 to 90 kg liveweight.

Rapeseed meal appears to have no specific effects on swine carcass lean and fat characteristics. Seale in 1952 (cited by Bowland, 1965a) observed improved carcass grades in swine fed rapeseed meal, but he attributed this to slower gains in the finishing period. Later, Seale showed that rapeseed meal had no effect on Record of Performance (R.O.P.)

carcass scores and measurements or on carcass grades. Hussar and Bowland (1959a) observed a significant reduction in loin eye area of pigs on a diet containing 10% rapeseed meal when the pigs were fed individually, but not when group-fed. Carcasses of pigs receiving rapeseed meal appeared to be shorter. Bowland (1951) reported shorter carcasses were obtained when pigs were fed thiouracil (a goitrogen with antithyroid action similar to that of rapeseed goitrogens). Manns and Bowland (1963a) reported no influence on carcass measurements or carcass grades when solvent-extracted rapeseed meal replaced all the soybean meal in the diet. Bell and Belzile (1965) showed that rapeseed meal had little influence on carcass quality, except that it tended to increase loin eye area. Bell, however, showed that feeding of rapeseed screenings to pigs receiving rapeseed meal tended to depress loin eye area, which agrees with the observations of Hussar (1958). Rapeseed screenings contain myrosinase, the enzyme which liberates rapeseed meal goitrogens, and the rapeseed meal used by Bell was reported to be myrosinase-free. In general, however, it has been shown that rapeseed meal has little effect on carcass measurements.

C. Reproduction and lactation

Reports on the effects of rapeseed meal on reproduction and lactation in swine are inconsistent Frölich and Haring (1937b) stated that up to 400 gm of rapeseed meal per head daily was satisfactory for nursing sows, and 200 gm daily was a maximum for young sows over 60 kg liveweight. Bell, in 1958 (cited by Bell and Belzile, 1965), replacing linseed meal with 7% rapeseed meal in diets for gilts, obtained unsatisfactory reproduction and lactation results. Rapeseed meal at this level depressed number of pigs born alive, and birth weight and weaning weight of litters, especially when Polish type meal was fed. Gilts on rapeseed meal diets lost more

weight from prior to farrowing to the end of lactation than control gilts.

Manns and Bowland (1963a) fed rapeseed meal in gestation and lactation diets to gilts at 0, 3, 6 and 12% of the diet. At 6 and 12% rapeseed meal, the gilts required 2 to 2.5 estrous cycle on the average before they conceived. Addition of lysine to the diet was of no benefit. The same authors reported poor lactation and reproductive performance with rats fed rapeseed meal. Kennedy and Purves (1941) stated that rapeseed meal caused a delay in ovary development. Delayed ovarian development might explain the slow conception observed by Manns. In the experiment of Manns (1962) gilts fed 12% rapeseed meal farrowed numbers of live pigs similar to the control gilts, but birth weight and five week weaning weights were lower for offspring of gilts fed 12% rapeseed meal. Such results suggest lactational inadequacy associated with rapeseed meal feeding. The author suggested that rapeseed meal should be restricted to 3% in pre-gestation, gestation and lactation diets.

D. Composition of Sows' Colostrum and Milk

1. Gross composition

Much work has been done on the yield and composition of sows' colostrum and milk because of the economic importance of early weaning. Sows' milk composition was first studied in the nineteenth century. Von Gohren, in 1865 (cited by Bowland, 1965b) obtained the following percentage values for total solids, fat, protein, milk sugar and ash, respectively: in colostrum--29.87, 9.53, 15.56, 3.84, 0.85, and in milk--13.87, 1.48, 7.91, 2.65, and 1.14.

In a review, Bowland (1965b) cited a review of von Neuhaus (1961) and, in a summary of data appearing in the literature since 1930, obtained the following mean values for sows' milk; percent total solids, fat,

protein, lactose, and ash respectively: 19.4, 7.2, 6.1, 4.8 and 0.96. Other studies of gross composition of sows' milk are those of Braude et al, (1947), who first used oxytocin for milk letdown in sows; Bowland et al (1949a and b), who also studied levels of vitamins A, C and D; Smith (1959a and b) and Evans (1959).

Perrin (1955) showed that as lactation progressed, percent total solids fell rapidly from about 30% at parturition to about 20% at 12 hours postpartum, and was approximately 21% from the second to the eighth week of lactation. Percent fat averaged 7 to 8% for the first day and increased to 9 to 10% for the duration of lactation. Protein was high (near 20%) at parturition and fell in the following 24 hours to 6 to 7%, where it stayed for the rest of lactation. Lactose levels went from 2.5% at parturition to 5% during the second week of lactation. Percent ash increased from 0.6 to 1.0%. Vitamin A (Bowland, 1965b) varied from 145 μg per 100 ml in colostrum to a low of 11 μg per 100 ml in sows' milk. Perrin (1955) felt that 4 to 7 days were required for the transition of colostrum to milk.

Beacom and Bowland (1951) reported essential amino acid levels in sows' colostrum and milk. Colostrum, compared to milk, had higher levels of threonine, phenylalanine, valine and leucine and lower levels of lysine and methionine expressed as a percent of the protein. All the amino acids measured except histidine were lower in sows' milk protein than in cows' milk protein.

Rook (1961) reviewed the causes of variation in chemical composition of milk of the cow. He noted effects of season, breed and age of animals, lactational stage and feeding regimen. In the cow, during a milking period, the first milk may have levels of 1% fat and strippings may have levels of 10% fat. In contrast, Whittlestone(1952) has noted that in the

sow, fat remains dispersed and fat content is constant throughout a milking. In cows (Rook, 1961),thyroid hormone leads to an increase in milk yield, a variable increase in percent fat and a small increase in lactose. Thiouracil,a goitrogen, has reverse effects.

The effects of feeding on sow milk composition have not been studied extensively. Smith, (1959b) observed that percent fat increased, percent protein showed no change and percent lactose decreased with decreasing feed intake of sows. Jarl, in 1951 (cited by Altschul, 1958), showed that rapeseed meal in sow diets depressed percent fat in the milk. Willet and Maruyama (1946) reported that the level of fat in sows' milk increased from 6.1% on a diet containing 2.8% fat to 9.6% on a diet containing 27.1% fat. DeMan and Bowland (1963) found that the inclusion of 15% stabilized tallow in sow diets resulted in levels of 8.4% fat in the milk compared to 6.2% fat in milk of sows on standard diets. Bowland et al (1951) observed that pasture-fed sows had significantly lower fat levels in their milk and lower protein levels in first day colostrum than dry-lot fed sows.

2. Fatty acid composition of milk fat

De la Mare and Shorland (1944) demonstrated by ester fractionation methods that the fat of hand-milked Berkshire sows contained 2.4, 1.8, 20.3, 6.1, 8.8, 35.0, 14.0 and 3.6 moles per cent, respectively of steam volatile fatty acids, myristic acid, palmitic acid, stearic acid, hexadecenoic acid, oleic acid, octadecadienoic acid and 20 to 22-carbon acids. In a recent study, DeMan and Bowland (1963) reported levels of fatty acids as a percent of milk fat of sows fed a diet to meet U.S. N.R.C. requirements were as follows: oleic, 35.3; palmitic, 30.3; linoleic, 13.0; palmitoleic, 9.9; stearic, 4.0; myristic, 3.3; linolenic,2.5; lauric, 0.3;

and capric, 0.2. The corresponding composition of colostrum fat was: oleic, 41.7; palmitic, 22.5; linoleic, 20.9; palmitoleic, 5.0; stearic, 5.7; myristic, 1.4; and linolenic, 2.4. Salmon-Legagneur (1964) fed sows 8% levels of maize and coconut oils during pregnancy and lactation. Groups fed maize oil during pregnancy and no supplemental oil during lactation (M-A) and groups fed maize oil during pregnancy and coconut oil during lactation (M-C) had high levels of linoleic acid in milk fat, and M-C groups had more lauric acid in milk fat than controls. Adding oil to diets led to increasing proportions of fatty acids in milk resulting from dietary sources and decreasing proportions from endogenous sources. Tollerz and Lindberg (1965) showed that addition of 6.3% cottonseed oil to sow diets led to doubling of linoleic acid content of milk fat, and 6.3% linseed oil (58% linolenic acid)raised linolenic acid content of milk fat from 1.1 to 18.3%. A compensating decrease in 14 and 16-carbon fatty acids was observed. Milk fat adjusted to dietary fat patterns in two to three days. A level of 16.7% cottonseed meal in diets led to 27% levels of linoleic acid in milk fat of sows. Garton (1963) stated that in fasting cows, levels of 4 to 14-carbon fatty acids were decreased in milk fat, and suggested that rapid synthesis of fat leads to increasing proportions of short chain fatty acids. However, his report suggested that in sows' milk fat the opposite appears to be true.

Ashworth, Ramaiah, and Keyes (1966) compared the fatty acid composition of milk from seven species of animals. They observed that short chain fatty acids (below 16-carbon) were much lower in milk fat of non-ruminants than in that of the ruminant animals listed.

DeMan and Bowland (1963) demonstrated higher levels of capric, lauric, myristic, palmitic and palmitoleic acids and lower levels of 18-carbon acids in sows' milk than in colostrum. Stinson (1966) reported, in

agreement with DeMan and Bowland, that myristic, palmitic, palmitoleic, stearic, oleic, linoleic, arachidic and gadoleic acids were respectively, 1.8, 22.8, 4.3, 4.5, 35.4, 27.3, 3.1 and 0.5% of colostral fat of sows, and 3.9, 30.8, 11.4, 3.8, 32.7, 14.3, 1.7 and 0.3% respectively of sows' milk fat. Fatty acids up to palmitic were significantly lower in colostral fat and fatty acids from stearic to the 20-carbon fatty acids were lower in milk fat.

Duncan and Garton (1966), in a recent study of sows' colostral and milk fat, demonstrated a reciprocal relationship between the levels of C 16:0 and C 18:1 fatty acids. They also demonstrated that C 16:0 (palmitic acid) was preferentially esterified to the second carbon atom of the glycerol portion of triglycerides, which observation agrees with observations of Stinson (1966).

EXPERIMENTAL

A. Objectives

These experiments were designed to study the effects on growth, gestation and lactation when 8% solvent-extracted rapeseed meal was substituted on a protein equivalent basis for soybean meal in the diets.

Specific experiments were designed to study:

(1) a) Rate of gain and efficiency of feed utilization of gilts through growing and pre-gestation periods,

b) reproductive performance of sows for two reproductive cycles,

c) gross composition of colostrum and milk and fatty acid composition of colostral and milk fat,

(2) a) rate of gain and efficiency of feed utilization from weaning to market weight of first litter progeny from sows,

b) digestible energy and nitrogen, and metabolizable energy and nitrogen of the diets when the progeny were 6 weeks of age and also when they were 40 kg liveweight.

B. Methods and Procedures

1. General

Experiment 1 was conducted from September, 1965 to December, 1966 and experiment 2, using progeny from sows in experiment 1, continued from July, 1966 to December, 1966.

Experiment 1 dealt with growth and reproductive performance of 24 gilts through two reproductive cycles. Feed consumption, daily gain, and efficiency of feed utilization were measured during growth and up to the first farrowing. Sows' colostrum and milk composition was studied after

the first farrowing with milk samples being obtained from 16 sows.

Experiment 2 was conducted with 32 first litter offspring of sows in experiment 1. Feed consumption, daily gain, efficiency of feed utilization, digestibility of nitrogen and energy, and carcass characteristics were studied. The pigs were identified at birth by ear notching and routinely treated for anemia prevention by injection of 2 ml of Pigdex 100 (contains 100 mg of injectable iron per ml) at 4 days of age. Males were castrated following weaning at 21 days of age. Pigs were treated for roundworms (ascarids) with a piperazine derivative and were vaccinated for erysipelas.

2. Formulation of experimental diets and methods of feeding

Diets were formulated to meet requirements as defined in the National Academy of Sciences--National Research Council Nutrient Requirements of Swine (1964; 1967, unpublished). In experiment 2, the starting diets were fed from the age of 3 weeks to 9 weeks; the growing diets from 9 weeks of age to 55 kg liveweight and the finishing diets from 55 kg to market weight of 90 kg. The gilts in experiment 1 were on a standard diet without rapeseed meal up to 12 weeks of age at which time they were allotted to experimental diets as outlined for experiment 2.

At 90 kg liveweight the gilts were put on the reproduction diets and individually fed 2.7 kg daily of feed. Two weeks after breeding and until transferred to farrowing pens, they were restricted to 2.3 kg of feed daily. On the day of farrowing they were given 0.45 kg of feed and 0.45 kg of bran. The bran was eliminated on the fourth day after farrowing. The feed intake of sows was increased to 2.3 kg daily plus 0.3 kg daily per pig in the litter by the seventh day after farrowing. At 20 days after farrowing, feed was reduced to 2.3 kg daily and held at

this level throughout the second gestation period. The sows, during the second farrowing and lactation were fed similarly to the method used in the first farrowing and lactation. Experiment 1 was terminated 21 days after the second farrowing of each sow at which time the litters were weaned.

Tables 1 and 2 show the formulation and composition of the experimental diets. The rapeseed meal diets were adapted from the basal diets by substituting rapeseed meal for wheat and soybean meal so that the diets remained isonitrogenous and approximately isocaloric. Table 2A lists the composition of the rapeseed meal used in the diets. All diets were ground, mixed and bagged at the University Livestock Farm elevator.

3. Experiment 1

a) Sow growth and reproduction experiments

In experiment 1, 24 gilts (6 littermate groups of 4 gilts each) were assigned to four lots which received the treatments shown in Table 3. One gilt from each of the 6 littermate groups was assigned to each of the four lots. The gilts averaged 29 kg liveweight when allotted. For the growing and finishing periods (29 to 90 kg), the gilts were group-fed in eight pens of three pigs each, and when they reached a weight of 90 kg, they were transferred to six pens of four pigs each fed individually. They were housed in a temperature-controlled building on concrete floors.

The gilts were mated to boars, according to the schedule in Table 4, at an average age of 230 days. The first mating period was for 43 days, from February 2 to March 17 to allow the possibility of two estrous periods, and the second mating period was from weaning of the first litter to 64 days after weaning according to the schedule in Table 4.

Table 1. Formulation of the diets on an air-dry basis

Diet	Starter		Grower		Finisher		Reproduction	
Rapeseed meal added	-	+	-	+	-	+	-	+
Diet number	1	2	3	4	5	6	7	8
Ingredients %								
Wheat	60.9	59.9	41.0	40.0	32.5	31.5	26.5	25.5
Barley	-	-	41.05	41.05	33.0	33.0	26.95	26.95
Oats	-	-	-	-	20.0	20.0	30.0	30.0
Oat groats	4.10	4.10	-	-	-	-	-	-
Dried skimmilk powder	5.00	5.00	-	-	-	-	-	-
Alfalfa meal	-	-	2.00	2.00	3.00	3.00	4.00	4.00
Soybean meal (44%)	10.00	3.00	10.00	3.00	8.00	1.00	9.00	2.00
Rapeseed meal	-	8.00	-	8.00	-	8.00	-	8.00
Fishmeal (72%)	7.00	7.00	2.00	2.00	-	-	-	-
Meat meal (55%)	1.20	1.20	2.00	2.00	2.00	2.00	2.00	2.00
Stabilized fat	3.00	3.00	-	-	-	-	-	-
Sucrose	5.00	5.00	-	-	-	-	-	-
Molasses	2.40	2.40	-	-	-	-	-	-
Ground limestone	0.20	0.20	0.50	0.50	0.50	0.50	0.50	0.50
Dicalcium phosphate	-	-	0.60	0.60	0.20	0.20	0.30	0.30
Iodized salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Zinc sulfate	0.05	0.05	0.05	0.05	0.05	0.05	-	-
Trace mineral mix[1]	0.15	0.15	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin B-complex mix[2]	0.30	0.30	0.10	0.10	0.10	0.10	0.10	0.10
Vitamins A and D_2[3]	+	+	+	+	+	+	+	+
Vitamin B_{12}	-	-	-	-	-	-	0.05	0.05
Antibiotic supplement TM-10[4]	0.20	0.20	0.10	0.10	0.05	0.05	-	-

[1]Contains the following minerals per kg of mineral mix: cobalt carbonate, 2.28 gm; copper sulphate ($CuSO_4 \cdot 5H_2O$), 24.50 gm; ethylene diamine dihydroiodide, 1.30 gm; ferrous carbonate, 234.80 gm; manganous oxide, 47.73 gm; zinc oxide, 2.96 gm; ground limestone, 686.43 gm.

[2]Contains the following B vitamins per kg of vitamin mix: riboflavin, 4.4 gm; calcium pantothenate, 8.8 gm; niacin, 19.8 gm; choline chloride, 21.4 gm; folic acid, 132.0 mg.

[3]Diets 1-6: To provide 200,000 I.U. vitamin A and 20,000 I.U. vitamin D_2 per 100 kg.
Diets 7-8: To provide 500,000 I.U. vitamin A and 50,000 I.U. vitamin D_2 per 100 kg.

[4]Contains 22 gm oxytetracycline per kg.

Table 2. Composition of the diets on an air-dry basis

Diet number		1	2	3	4	5	6	7	8
Soybean meal[1]	%	10.0	3.0	10.0	3.0	10.0	3.0	10.0	3.0
Rapeseed meal[1]	%	0.0	8.0	0.0	8.0	0.0	8.0	0.0	8.0
Components									
Gross energy	kcal/kg	4284*	4256*	3943*	3924*	4370+	4360+	4220+	4210+
Digestible energy (calculated)	kcal/kg	3470	3440	3360	3330	3260	3240	3190	3170
Digestible energy (analysis)	kcal/kg	3644	3609	3254	3174				
Metabolizable energy (analysis)	kcal/kg	3517	3488	3135	3059				
Crude protein (calculated)	%	22.1	22.1	17.5	17.6	15.7	15.8	16.2	16.1
Crude protein (analysis)	%	22.7	21.5	18.0	18.2	16.0	15.7	16.0	16.0
Digestible protein (analysis)	%	19.1	17.7	15.0	15.0				
Metabolizable protein (analysis)	%	12.6	11.2	7.4	7.7				
Lysine (calculated)	%	1.14	1.09	0.84	0.79	0.69	0.64	0.72	0.66
Crude fat (analysis)	%	5.2	5.2	2.2	2.2	2.9	3.2	3.6	3.7
Ash (analysis)	%	3.2	3.4	3.8	4.0	3.3	3.6	4.3	4.0

[1]In subsequent tables soybean meal is referred to as SM and rapeseed meal as RM.

*Values obtained by analysis

+Calculated values

Table 2A. Composition of rapeseed meal compared to soybean meal

	Gross energy kcal/kg	DE[1] kcal/kg	ME[1] kcal/kg	Crude protein %	Digestible protein %	Lysine %	Crude fat %	Ash %
Rapeseed meal	4380*	3000**	1760++	34.4*	26.8**	2.0*	1.9*	5.9*
Soybean meal	4200**	3300**	2640++	45.8**	43.1**	2.9**	1.3**	5.8**

[1]DE -- digestible energy
ME -- metabolizable energy
*Values obtained by analysis
+Calculated values
**Values from NRC nutrient requirements of swine (1964)
++Values from Clandinin and Robblee (1966)

Table 3. Allotment of gilts to experimental diets -- experiment 1

Lot	1	2	3	4
Dietary treatment[1]				
Growth to 106 kg	SM	RM	RM	SM
106 kg to reproduction	SM	RM	SM	RM
No. of gilts	6	6	6	6
Avg wt. on test kg	28.4	28.4	29.5	29.3
Avg age on test days	84	84	84	84

[1]The gilts were group-fed by lots during growth and were individually restricted-fed during reproduction.

Table 4. Breeding schedule

Gilt litter group number[1]	200	220	240	270	280	290
Breed of gilts[2]	Y	LacLandY	YLacY	HYLacY	YLandLacY	YLacY
Boar - first breeding	Y	Y	HY	HY	HY	Lac
Boar - second breeding	Y	Y	Lac	Lac	Y	Lac

[1]Each group was 4 littermate gilts allotted across the 4 treatments.
[2]Y, Lac, Land, and H stand for the breeds Yorkshire, Lacombe, Landrace and Hampshire, respectively.

In both gestation periods, the sows were transferred to farrowing pens 106 days after their last mating, and they were kept there until their litters were weaned at 21 days of age. Weaned pigs were put on a starting diet which contained a level of 0 or 8% rapeseed meal, according to the diet of their dam, until allotted to the growing experiment 2. First litter pigs were weaned throughout June and in early July, 1966, and the sows were transferred immediately to outdoor dry-lot facilities for rebreeding.

b) Lactation experiments

Milk samples were obtained from 16 sows (4 per lot) 8 to 12 hours and 7 days after farrowing of the litters in experiment 1. Pigs were removed from the sow at least 1 hour before milking. Milk letdown was induced by injection of 1 ml of Pitocin (10 IU of oxytocin per ml) into an ear vein. Milk yield was not determined, but a sample of from

100 to 400 ml was obtained. Milk was collected in amber colored glass containers which were air-tight when sealed. Within 2 hours the sample was placed in a cold storage room at 4 C and within 48 hours the sample was lyophilized in a freeze-drying apparatus.

4. Experiment 2 -- Growth and metabolism experiments

In experiment 2, 4 pigs (2 males and 2 females) from each of 8 litters from lots 1 and 2 of experiment 1 were assigned to 4 lots. The 16 pigs from dams in lot 1 (receiving basal diet) were allotted at random to lots 1 and 4. Pigs from dams in lot 2 (receiving 8% rapeseed meal) were similarly allotted to lots 2 and 3. Male and female pigs were fed separately. Lots 1 and 3 were fed rapeseed meal diets and lots 2 and 4 were fed basal diets (Table 5). The pigs averaged 33 days of age and 5.9 kg liveweight at allotment. They were group-fed in lots of four.

Digestible and metabolizable energy and nitrogen were determined at 6 weeks of age and again at 40 kg liveweight on all male pigs in experiment 2. For the metabolism trials at 6 weeks of age, pigs were housed in small animal cages described by Hussar and Bowland (1959b) The pigs were fed the diets for at least 1 week prior to collection. They were put in the cages within $\pm$ 3 days of 6 weeks of age. They were acclimatized to the cages for 3 days, and urine and feces were then collected daily for a 3-day period. Feces were collected on a 12 mesh screen below the cages, and urine was collected

in pans below the screen and the urine funnelled into approximately 1-liter glass receptacles. The urine was acidified by addition of 25 ml 50% (v/v) H_2SO_4 to the receptacles prior to collection. The total fecal collection and a urine sample were stored at 4 C until placed in a drying oven. The feces were dried in a tray at 60 C in a forced-air oven over a period of 60 hours. The dried feces were allowed to equilibrate with atmospheric moisture for 24 hours. Random samples were shown to contain 8% moisture.

When the pigs reached a liveweight of 40 kg or over on the regular Tuesday weighing, they were transferred to metabolism crates for the second time. These crates were described by Hussar (1958). A 3-day acclimatization period was used and feces and urine were collected separately over a 3-day period. Urine was received in 10-liter plastic pails containing 50 ml 50% H_2SO_4. Feces and urine were collected, stored, dried and analyzed as for the younger pigs.

Table 5. Allotment of progeny to experimental diets -- experiment 2

Lot		1	2	3	4
Treatment					
Dams' diet		SM	RM	RM	SM
Diet fed to progeny		SM	RM	SM	RM
No. of pigs		8	8	8	8
Avg wt on test	kg	6.0	5.8	5.9	6.0
Avg age on test	days	33	31	35	33

5. Methods of chemical analysis

Chemical analyses of feces and urine were similar for both digestion trials except for determination of the energy in urine. The dried feces were ground in a Wiley mill to pass through a 20 mesh screen. Energy in feces and urine was determined by combustion in a Parr oxygen bomb calorimeter. For the determination of energy in urine in the first trials, a 50 ml sample of urine was mixed with 10 gm of soluble starch and dried for 12 hours at 60C in a forced-air oven. The dry material was combusted in the bomb calorimeter and a blank was determined with starch alone. The difference in caloric content between the sample and the blank was taken to represent the energy content of urine. In the trials with 40 kg pigs, a 100 ml sample of urine was lyophilized in a freeze-dryer, and the dry urinary material was combusted directly in the bomb calorimeter. Percent dry matter in urine was determined with 5 ml samples which were lyophilized in small freeze-drying bulbs.

For the determination of nitrogen, the Kjeldahl method was used (AOAC, 1964). To calculate protein levels, a factor of 6.25 was used. Moisture, fat, and ash were determined by the official methods of the

AOAC (1964).

With colostrum and milk, total solids, protein, ash, solids-not-fat, lactose, and fat as a percent of whole milk, and fatty acids as a percent of fat were determined. Total solids, protein and fat were determined by AOAC (1964) methods, solids-not-fat was determined by difference between percent total solids and percent fat, and lactose was determined by subtracting percent fat, protein and ash from total solids.

To prepare for fatty acid determinations, the freeze-dried colostrum and milk were dissolved in water; and the fat was extracted by the Majonnier method, using a 50/50 (v/v) mixture of ethyl ether and light petroleum ether. The extracted fat was transferred to a 5 ml freeze-drying bulb and esterfied according to the method of DeMan (1964). The esters were injected directly into a gas chromatograph. The instrument used was an F & M model 720 dual column temperature-programmed gas chromatograph equipped with 10 ft (305 cm) columns packed with 20% (w/w) diethyleneglycol succinate (DEGS) on 60/80 mesh firebrick. Column temperature was programmed from 100 to 220 C at a rate of 7.5 per minute. The detector, a thermal conductivity type, was set at 265 C and the injection port at 245 C. Helium carrier gas was used and the flow rate was adjusted to 50 ml per minute. Sample size was 10 to 20μl, and the attenuation setting was 32 for the major large peaks, 8 for the smaller peaks and 2 for trace components (below 1%). A Minneapolis-Honeywell strip chart recorder was attached. A planimeter was used to measure peak areas on the chromatograms. To calculate weight percent of the fatty acids, correction factors (DeMan and Bowland, 1963) were applied to area figures and the corrected figures were converted to weight percent by taking them as a percent of total area of all peaks on

the chromatogram. Peaks were identified by 'spiking' esterified fat samples with pure standard fatty acid esters and by a semilogarithmic plot of carbon number vs. logarithm of the retention time (see appendix 1).

6. Methods of statistical analysis

An IBM 7040 computer in the Department of Computing Science was used to statistically analyze all data. A probability of 0.05 was selected as the point of significance for most of the data. For some of the data, particularly that on reproduction, a 10% level of significance was used for interpretation of the results, with some reservations. This level of significance was used because reproductive data of swine tend to vary widely between replicates and within treatments, making statistical analysis difficult. Program BMD02V was used for analysis of variance and program BMD03V was used for analysis of covariance. All data was converted to metric units before statistical analysis. Duncan's new multiple range test (Steele and Torrie, 1960) was used to test differences between multiple means.

Missing data were replaced by the average value of the group from which the data were missing, and in the analysis of variance, error degrees of freedom were reduced by one for each missing value. Data for one sow were missing for the gross and fatty acid composition of milk in experiment 1 and for one pig for the digestibility studies on the growing diets in experiment 2.

RESULTS AND DISCUSSION

A. Growth, Reproduction and Lactation of Sows -- Experiment 1

1. Feed consumption, daily gain and efficiency of feed utilization during pre-gestation

The means for each lot for average daily feed, average daily gain and efficiency of feed utilization for experiment 1 are listed in Table 6. The statistical analysis of these data and treatment means for each factor are given in Table 7.

a) Average daily feed

No significant differences in feed consumption were observed in the growing period (29 to 55 kg liveweight), the finishing period (55 to 90 kg liveweight), the 'transition' period (90 to 106 kg liveweight, group-feeding), or the pre-gestation period (106 to 116 kg liveweight, individually fed to the time of breeding). However, pigs fed rapeseed meal consistently consumed slightly less feed during the growing, finishing and transition periods. Manns (1962) and Hussar (1958) observed a depression in feed intake of group-fed pigs receiving rapeseed meal.

At the beginning of the pre-gestation period, lot 3 was changed from the rapeseed meal diet to the soybean meal diet, and lot 4 was changed from the soybean meal diet to the rapeseed meal diet. All lots were individually fed at this time, and feed intake was restricted to 2.7 kg daily. On individual feeding, few pigs consumed their allotted feed and average daily feed was 1.8 kg. In the first 2 weeks on this feeding schedule, feed intake of lot 3 pigs was lower than for all other groups. For lot 4 (changed from the soybean meal to the rapeseed meal diet), feed intake during this same period was higher than for all other

groups. This indicated that the palatability of rapeseed meal was not a problem, but that conversely, changing from rapeseed meal diets to soybean meal diets may give problems in acceptability. Feed consumption during gestation will be discussed under reproductive performance.

Table 6. Average daily feed, average daily gain, and efficiency of feed utilization -- experiment 1.

Lot	Feeding period	Rapeseed meal for[1] growth	reproduction	No. of pigs	Avg daily feed kg	Avg daily gain gm	Feed/ kg gain kg
1	Growing	-	-	6	2.08	695	2.99
2		+	+	6	2.04	663	3.08
3		+	-	6	2.00	705	2.84
4		-	+	6	2.08	709	2.94
1	Finishing	-	-	6	3.17	914	3.48
2		+	+	6	3.42	895	3.84
3		+	-	6	2.96	809	3.68
4		-	+	6	3.73	954	3.91
1		-	-	6	2.68	817	3.29
2	Growing	+	+	6	2.81	791	3.56
3	and	+	-	6	2.55	763	3.35
4	Finishing	-	+	6	2.97	840	3.54
1		-	-	6	2.82	413	6.82
2	Transition-	+	+	6	2.88	350	8.23
3	group-fed	+	-	6	2.67	322	8.23
4		-	+	6	3.01	454	6.60
1		-	-	6	1.86	160	-[2]
2	Pre-gestation	+	+	6	1.73	128	-
3	-individually	+	-	6	1.71	172	-
4	fed	-	+	6	1.89	188	-

[1]+ indicates a level of 8% rapeseed meal in the diet and - indicates no rapeseed meal

[2]- these values were not determined.

Table 7. Treatment means for average daily feed, average daily gain and efficiency of feed utilization -- experiment 1

Feeding period	Treatment Diet to 89 kg	No. of pigs	Avg daily feed kg	Avg daily gain gm	Feed/ kg gain kg
Growing	SM	12	2.08	702	2.96
	RM	12	2.02	684	2.96
Finishing	SM	12	3.45	934	3.70
	RM	12	3.19	852+	3.76
Growing and finishing	SM	12	2.78	828	3.48
	RM	12	2.68	777+	3.46
Transition[1]	SM	12	2.92	434	6.71
	RM	12	2.78	336*	8.23*
Pre-gestation	SM	12	1.88	174	-
	RM	12	1.72	150	-

[1]Pigs were group-fed in the transition period and individually fed in the pre-gestation period. At the end of this period, one lot was changed from the basal to the rapeseed meal diet, one lot was changed from the rapeseed meal diet to the basal diet and two lots were not changed.

+$P < 0.10$

*$P < 0.05$

b) Average daily gain

In the growing period, gilts fed rapeseed meal grew 18 gm per day less than those fed soybean meal (not significantly different). In the finishing period, pigs fed rapeseed meal grew 82 gm per day less than those fed soybean meal ($P < 0.10$), and this appeared to be associated with a decreased feed intake. In the combined growing and finishing periods, the gilts grew 51 gm daily less ($P < 0.10$) when fed 8% rapeseed meal as compared to those fed the basal soybean meal diets. This

depression of growth is in agreement with the findings of Manns (1962).

In the transition period (from 90 to 106 kg liveweight), average daily gain of gilts fed rapeseed meal was 98 gm less ($P < 0.05$) than of those fed soybean meal diets. The reason for this difference was not evident, but possibly the stress of moving and changing environment affected more severely pigs fed rapeseed meal. When the feed was changed and individual feeding was begun (pre-gestation period), those changed to the soybean meal diet from the rapeseed meal diet did not gain or lose weight on the average in the first 2 weeks on this diet (4 out of 6 pigs lost weight), while those changed to rapeseed meal diets from the soybean meal diets gained on the average 180 gm daily in the same period. However, during the whole pre-gestation period (106 kg to breeding time), sows fed rapeseed meal for growth and rapeseed meal for reproduction (R-R*) grew most slowly.

c) Efficiency of feed utilization

Efficiency of feed utilization, measured as kg of feed per kg of gain was similar for pigs fed rapeseed meal and those fed soybean meal for the growing and finishing periods. During the growing period all pigs consumed 2.96 kg of feed per kg of gain and during the finishing period, they consumed 3.73 kg of feed per kg of gain. In the transition period, pigs fed rapeseed meal required an additional 1.52 kg of feed per kg gain than was required by pigs fed soybean meal, a difference of 23% more feed per kg gain ($P < 0.05$). During pre-gestation, feed efficiency was not calculated since several animals lost weight and values

*The lots are designated as B-B, R-R, R-B, and B-R as follows: B-B, soybean meal diet (basal) for growth and for reproduction; R-R, rapeseed meal diet for growth and for reproduction; R-B, rapeseed meal diet for growth and soybean meal diet for reproduction; and B-R, soybean meal diet for growth and rapeseed meal diet for reproduction.

obtained would have little meaning.

2. Reproductive performance

Tables 8, 9 and 10 list the means of the reproductive and breeding traits measured for the first litter, for the second litter and treatment means for diet and litter, respectively.

a) First litter

When the sows were bred for the first time, two sows failed to conceive. These sows were littermates; one was in lot 2 (R-R) and one was in lot 3 (R-B). The sows were slaughtered, and examination of the reproductive tracts* revealed that no corpora lutea were present, and ovaries appeared to be smaller than normal. It was concluded that the reproductive tracts were infantile; that is, not fully developed.

During gestation, daily feed was restricted to 2.3 kg, and consumption was 2.2 kg daily on the average, with little variation between groups. Average daily gain was also similar for all groups. No differences between lots in feed efficiency which averaged 4.54 kg feed per kg gain, were observed.

The breeding performance of sows in this study was not affected by the feeding of rapeseed meal. The number of services to conception, weight at breeding, gestation gains, lactation losses, and the change in weight of the sows from breeding to weaning of the litters were not affected by dietary treatments. These results differ from those of Manns (1962) who showed that sows fed rapeseed meal had to be bred 2 to 2.5 times before conception occurred.

At farrowing time, one sow in lot 1(B-B) farrowed 5 dead pigs and died 2 days later due to unknown causes. Post-mortem findings showed

*The advice of Dr. T.D.D. Groves, Assistant Professor of Physiology, is acknowledged.

2 macerated feti in the uterus. A sow in lot 4 (B-R), farrowing on the same date (June 24), farrowed 3 dead pigs, and died 3 days later. A tear in the uterine wall was found on post-mortem examination, and 6 piglets were found in the abdominal cavity. The cause of death was severe peritonitis. The loss of 4 sows, 2 due to non-conception and 2 due to death of the sows at farrowing time, left the lots balanced with 5 sows per lot.

Table 8. Reproductive performance -- first litters, experiment 1

Lot		1(B-B)	2(R-R)	3(R-B)	4(B-R)
Growing diet		SM	RM	RM	SM
Reproduction diet		SM	RM	SM	RM
Reproductive traits					
Number of litters[1]		5	5	5	5
Gestation data					
Number of services to conception		1.0	1.0	1.4	1.2
Breeding weight	kg	116	114	117	120
Average daily feed	kg	2.18	2.10	2.21	2.23
Average daily gain	kg	0.47	0.50	0.49	0.49
Feed per kg gain	kg	4.56	4.28	4.49	4.64
Total gestation gain	kg	56.1	52.4	51.9	48.6
Length of gestation	days	115	115	115	114
Lactation data					
Feed during lactation	kg	79.4	67.6	65.5	84.0
Lactation loss	kg	13.5	19.3	11.0	12.0
Increase in sow's weight (breeding to weaning of litters)	kg	26.5	22.2	26.1	22.7
Litter data					
Number of pigs born		10.2	10.6	9.0	9.8
Number of live pigs born		$9.8^{a,b}$	10.0^{a}	7.8^{b}	$9.4^{a,b}$
Number of pigs weaned		$8.0^{a,b}$	$6.2^{a,b}$	5.6^{a}	8.8^{b}
Litter birth weight	kg	13.5	12.2	11.5	12.2
Litter weaning weight	kg	41.1	26.7	31.0	41.3
Avg pig birth weight	kg	1.36	1.23	1.48	1.42
Avg pig weaning weight	kg	5.13	4.25	5.60	5.06

[1]One sow failed to farrow in each lot. Sows in lots 2 and 3 that failed to farrow did not conceive.

[ab]Figures with different superscripts are different at $P < 0.05$ as determined by Duncan's multiple range test (Steele and Torrie, 1960).

Table 9. Reproductive performance -- second litters, experiment 2

Lot		1(B-B)	2(R-R)	3(R-B)	4(B-R)
Growing diet		SM	RM	RM	SM
Reproduction diet		SM	RM	SM	RM
Reproductive traits[1]					
Number of litters[2]		4	4	4	4
Gestation data					
Number of services to conception		1.25	2.0	1.0	1.0
Breeding weight	kg	145	148	144	140
Total gestation gain	kg	46.8	48.8	41.0	46.0
Length of gestation	days	115	114	115	115
Lactation data					
Lactation loss	kg	15.3	18.6	14.7	15.3
Increase in sows' weight (breeding to weaning of litters)	kg	22.7	22.1	21.2	24.3
Litter data					
Number of pigs born		10.8	10.0	9.5	10.0
Number of live pigs born		10.0	9.8	9.5	9.5
Number of pigs weaned		9.5	7.8	8.8	8.8
Litter birth weight	kg	14.8	14.1	14.9	13.6
Litter weaning weight	kg	50.0	46.5	51.7	45.8
Avg pig birth weight	kg	1.46	1.45	1.58	1.45
Avg pig weaning weight	kg	5.28	5.25	5.94	5.34

[1]No significant differences were observed for any traits.

[2]Results for one litter in lot 1 and one in lot 4 were removed so that the number of litters per lot was balanced. One sow in lot 2 and one in lot 3 failed to conceive.

Table 10. Treatment means for reproductive performance

Reproductive traits		Litter no. 1	Litter no. 2	Growing diet SM	Growing diet RM	Reproduction diet SM	Reproduction diet RM	Mean
Number of litters[1]		16	16	16	16	16	16	32
Gestation data								
Number of services to conception		1.1	1.3	1.1	1.2	1.1	1.2	1.2
Breeding weight	kg	117	144	130	131	130	131	130
Gestation gain	kg	53.0	45.6	49.7	49.0	49.3	49.5	49.3
Lactation data								
Lactation loss	kg	14.9	16.0	14.5	16.4	12.8	18.1	15.4
Increase in sows' weight (breeding to weaning of litters)	kg	24.9	22.6	24.8	22.7	25.4	22.2	+23.7
Litter data								
Number of pigs born		10.2	10.1	10.2	10.0	9.8	10.5	10.1
Number of live pigs born		9.3	9.7	9.6	9.4	9.2	9.8	9.5
Number of pigs weaned		7.2*	8.7	8.9	7.0	8.0	8.0	8.0
Litter birth weight	kg	12.2+	14.3	13.3	13.2	13.4	13.2	13.2
Litter weaning weight	kg	34.7**	48.5	44.5*	38.6	43.2	40.0	41.6
Avg pig birth weight	kg	1.32*	1.48	1.40	1.42	1.46	1.35	1.40
Avg pig weaning weight	kg	4.92*	5.45	5.16	5.21	5.48	4.90	5.19

+ $P < 0.10$
* $P < 0.05$
** $P < 0.01$

[1]Data are included only for sows farrowing in both the first and second reproductive cycles.

A difference between 2 lots ($P < 0.05$) in the number of live pigs farrowed was observed. The R-R lot (lot 2) farrowed 2.2 live pigs less per litter than the R-B lot (lot 3).

A difference ($P < 0.05$) associated with dietary treatments during growth was found in the number of pigs weaned when these values were adjusted by analysis of covariance for the number of live pigs born. The sows fed rapeseed meal diets during growth (lots 2 and 3) weaned, on the average 5.9 pigs per litter and those fed soybean meal diets for this

period weaned 8.4 pigs per litter. These results suggest that the feeding of rapeseed meal during growth impaired future milk producing ability of sows. This is in general agreement with the observations of Manns (1962) who suggested that lactation was impaired by the feeding of rapeseed meal to females during growth and reproduction. For the first litter, a difference in litter weaning weights ($P < 0.05$) was observed. This difference amounted to 12.4 kg per litter or 30% lower litter weaning weights for the sows fed rapeseed meal during growth.

No differences were observed in total number of pigs born, litter birth weight, average pig weaning weight and average pig birth weight associated with the feeding of 8% rapeseed meal during growth or reproduction or both. Bell and Belzile (1965) reported that dietary rapeseed meal led to a depression in number of pigs born alive, birth weight and weaning weight of litters. Manns and Bowland (1963a) observed that the number of pigs born per litter was similar for sows fed rapeseed meal and those fed soybean meal diets.

b) Second litter

When rebred, the sows conceived an average of 10 days after weaning of the first litters. One sow in lot 2 (R-R) and one in lot 3 (R-B) failed to conceive when bred for 3 consecutive estrous cycles. These sows were in the same lots in which sows failed to conceive in the first reproductive cycle, and in this case again the two sows were littermates. The reproductive tracts of these two sows were examined. In the sow from lot 2, apparently no follicles had ruptured in the previous 5 weeks, and no corpora lutea were observed on either ovary. The ovaries and uterus of both sows appeared normal. The failure of 4 sows to conceive in two reproductive cycles in lots fed rapeseed meal for growth suggests

impairment of reproductive ability associated with feeding of rapeseed meal to young female swine.

Reproductive performance for the second litters was analyzed by removing data for one sow in lot 1 and one sow in lot 4, both of which were littermates of the sows failing to conceive, leaving the groups balanced with 4 litters per lot for statistical analysis. When the lots were balanced this way, no differences in measured reproductive traits were observed in the second litter. Any harmful effects of rapeseed meal appear to affect gilts more than sows in their second litter and may, as Kennedy and Purves (1941) suggested for rats, be associated with a delay in ovary development. These data also suggest that certain litter groups may be affected more than others.

c) First and second litters

Average birth weight, average weaning weight and numbers of pigs weaned were greater ($P < 0.05$) for the second than for the first litter, and litter weaning weights were higher ($P < 0.01$). Gestation gain for the first litter was greater than for the second ($P < 0.05$). No differences between first and second litters were observed in number of live pigs farrowed, lactation losses of the sows, and changes in sows' weights from breeding to weaning of litters. Birth weight of the second litter was greater at the 10% level of significance.

3. Lactation studies

Tables 11, 12, 13 and 14 list, respectively, the gross composition of sows' colostrum and milk, treatment means for gross colostrum and milk composition, fatty acid composition of sows' colostral and milk fat and treatment means for fatty acid composition.

Table 11. Gross composition of colostrum and milk

Lot		1	2	3	4
Feed for growth		SM	RM	RM	SM
Feed for reproduction		SM	RM	SM	RM
Colostrum					
Total solids	%	20.67[b]	23.33[a,b]	24.12[a]	23.61[a,b]
Fat	%	6.40[b]	7.71[a,b]	8.37[a]	6.72[a,b]
Solids-not-fat	%	14.27	15.62	15.88	16.94
Protein	%	8.80[b]	10.85[a,b]	10.43[a,b]	11.59[a]
Lactose	%	4.81	4.14	4.65	4.69
Ash	%	0.66	0.63	0.67	0.61
Milk					
Total solids	%	18.49	20.82	19.50	18.59
Fat	%	6.83	8.06	7.61	6.17
Solids-not-fat	%	11.66	12.77	11.83	12.41
Protein	%	5.25	5.48	5.63	5.35
Lactose	%	5.70	6.49	5.49	6.33
Ash	%	0.71	0.79	0.77	0.74

[ab]Numbers with different superscripts are different at $P < 0.05$.

Table 12. Treatment means for gross composition of colostrum and milk

		Growing diet		Reproduction diet				
		SM	RM	SM	RM	Colostrum	Milk	Mean
Colostrum								
Total solids	%	22.14	23.72+	22.40	23.47	22.93*	19.35	21.18
Fat	%	6.56	8.04*	7.38	7.22	7.30	7.17	7.24
Solids-not-fat	%	15.60	15.75	15.08	16.33	15.68**	12.17	13.92
Protein	%	10.20	10.64	9.62	11.22	10.42**	5.43	7.92
Lactose	%	4.75	4.40	4.73	4.42	4.57**	6.00	5.28
Ash	%	0.63	0.65	0.66	0.62	0.64**	0.75	0.70
Milk								
Total solids	%	18.54	20.16	19.00	19.70			
Fat	%	6.50	7.84	7.22	7.11			
Solids-not-fat	%	12.04	12.30	11.74	12.59			
Protein	%	5.30	5.56	5.54	5.42			
Lactose	%	6.02	5.99	5.60	6.41			
Ash	%	0.73	0.78	0.74	0.76			

+P $\leq$ 0.10
*P $\leq$ 0.05
**P $\leq$ 0.01

Table 13. Fatty acid composition of sows' colostral and milk fat

Lot	Colostral fat 1	2	3	4	Milk fat 1	2	3	4
Feed for growth	SM	RM	RM	SM	SM	RM	RM	SM
Feed for reproduction	SM	RM	SM	RM	SM	RM	SM	RM
Fatty acids-% of total								
C 10:0 (capric)	-[1]	-	-	-	0.16	0.15	0.18	0.26
C 12:0 (lauric)	-	-	-	-	0.22	0.23	0.24	0.34
C 14:0 (myristic)	1.52	1.40	1.58	1.62	2.92[b]	3.07[b]	3.46[ab]	3.87[a]
C 14:1 (myristoleic)	0.04	0.06	0.11	0.08	0.11	0.14	0.15	0.23
C 16:0 (palmitic)	22.51	21.70	22.71	23.05	26.70	26.52	26.64	29.34
C 16:1 (palmitoleic)	5.18	5.16	5.10	4.63	7.74[b]	7.58[b]	8.89[ab]	10.29[a]
C 18:0 (stearic)	5.16	4.52	4.99	5.51	4.72	4.34	4.09	4.06
C 18:1 (oleic)	41.14	44.05	39.91	39.68	41.39	43.57	40.53	36.67
C 18:2 (linoleic)	19.77	19.72	20.46	21.17	13.26	11.57	12.45	11.81
C 20:0[2] (arachidic)	1.81	1.58	1.85	1.51	0.99	1.04	1.10	1.05
C 20:4 (arachidonic)	0.94	-	0.90	0.28	0.68	0.26	0.76	0.58
C 14:0, 16:0 & 18:0	30.64	28.59	30.91	31.55	35.47	35.10	35.60	39.84
C 16:1, 18:1 & 18:2	69.36	71.41	69.09	68.45	64.53	64.90	64.40	60.16

[ab]Values with different superscripts differ at $P < 0.05$.

[1]Levels were not detectable.

[2]C 18:3 peak covered by this peak on chromatogram, so this value includes both C 18:3 and C 20:0 fatty acids.

Table 14. Treatment means for fatty acid composition of colostral and milk fat

Fatty acids % of total	Growing diet SM	Growing diet RM	Reproduction diet SM	Reproduction diet RM	Colostrum**	Milk	Mean
C 10:0 (milk fat only)	0.21	0.16	0.17	0.20	0.00[1]	0.19	
C 12:0 (milk fat only)	0.28	0.24	0.23	0.28	0.00	0.26	
C 14:0	2.48	2.38	2.38	2.48	1.53	3.33	2.43
C 14:1	0.11	0.12	0.10	0.13	0.07	0.16	0.12
C 16:0	25.40	24.39	24.64	25.15	22.49	27.30	24.90
C 16:1	6.95	6.68	6.73	6.91	5.02	8.62	6.82
C 18:0	4.86	4.48	4.74	4.60	5.04	4.30	4.67
C 18:1	39.72	42.01	40.74	41.00	41.19	40.54	40.87
C 18:2	16.50	16.04	16.49	16.06	20.28	12.27	16.28
C 20:0[2]	1.34	1.39	1.44	1.30	1.69	1.04	1.37
C 20:4	0.62	0.48	0.82	0.28	0.53	0.57	0.55
C 14:0, 16:0 & 18:0	34.38	32.54	33.16	33.77	30.42	36.50	33.46
C 16:1, 18:1 & 18:2	65.62	67.46	66.84	66.23	69.58	63.50	66.54

**$P < 0.01$

[1]Levels were not detectable.

[2]C 18:3 peak covered by this peak on chromatogram, so this value includes both C 18:3 and C 20:0 fatty acids.

a) Gross colostrum and milk composition

For the colostrum, a difference of 3.4% in total solids ($P < 0.05$) was observed between the B-B group (20.7%) and the R-B group (24.1%). However, the R-R group was not different from the B-B group, so the differences observed in total solids cannot be attributed directly to diet. Percent fat in the B-B group was lower ($P < 0.05$) at 6.4% than that of the R-B group, at 8.4%. In the two lots fed rapeseed meal for growth (lots 2 and 3), percent fat was higher than for those fed soybean meal diets (8.0 compared to 6.6%). No differences associated with diet were observed in percent solids-not-fat (SNF), protein, ash or lactose of sows' colostrum.

Compared to colostrum, sows' milk had lower levels of total solids ($P < 0.05$), SNF, and protein and higher levels of ash ($P < 0.01$ for the last three components). No differences in percent fat were observed between milk and colostrum of the sows. In sows' milk, no significant differences associated with diet were observed between lots in any of the components measured. Percent fat and percent solids appeared to be higher in milk of sows fed rapeseed meal for growth.

b) Fatty acid composition

No differences due to dietary treatments were observed in fatty acid levels in the fat of colostrum. Percent saturated fat and percent unsaturated fat did not vary between lots. Only traces of C 10:0 (capric) and C 12:0 (lauric) fatty acids were observed in the colostral fat of sows, which agrees with the results of DeMan and Bowland (1963) and Stinson (1966).

All fatty acid levels measured in sows' milk fat were different from those of colostrum ($P < 0.01$), with the exception of C 18:1

(oleic) - the major component, and C 20:4. Diet did not have a significant effect on fatty acid levels in the fat of sows' milk. C 14:1 and C 14:0 appeared to be higher in fat of the milk of lot 4 (B-R) sows than that of lots 2 and 3 sows, which received rapeseed meal diets during the growth periods. Levels of saturated fatty acids appeared to be higher (not significant) in the milk fat of lot 4 sows than that of other groups. Saturated fatty acids were 39% of the fat for lot 4 and 35% of milk fat for the other 3 lots.

B. Progeny Growth Studies -- Experiment 2

1. Feed consumption, daily gain and efficiency of feed utilization

Table 15 shows the lot means for feed consumption, average daily gain and efficiency of feed utilization for experiment 2. Treatment means are listed in table 16.

a) Average daily feed consumption

Dietary rapeseed meal led to a depression ($P < 0.05$) of 280 gm feed per day in the finishing period (55 kg to 89 kg liveweight) as compared to dietary soybean meal. In the starting period (6 kg to 18 kg liveweight), pigs fed rapeseed meal ate 4.7% less than those fed soybean meal diets, in the growing period (18 to 55 kg liveweight), 1.6% less, and in the combined starting, growing and finishing periods, 3.4% less, none of which were significantly different. These observations are in agreement with earlier observations in this report on growing gilts. Hussar and Bowland (1959a) and Seale in 1952 (cited by Bowland, 1965a), reported variable effects of rapeseed meal on feed consumption, although Manns and Bowland (1963a) reported that rapeseed meal did not affect feed intake.

Male pigs consumed significantly more feed than females ($P < 0.05$). The multiple range test showed that males fed rapeseed meal diets gained

less than males fed soybean meal diets in the finishing period ($P < 0.05$). However, significant interactions were not observed between sex and dietary treatment when compared by an F-test in analysis of variance.

b) Average daily gain

Pigs fed soybean meal diets grew 10% more rapidly throughout the period from 6 to 89 kg liveweight as shown by a difference of 64 gm average daily gain when compared to pigs fed rapeseed meal diets ($P < 0.05$). This observation is in agreement with observations of Manns and Bowland (1963a), Hussar and Bowland (1959a) and Seale in 1952 (cited by Bowland, 1965a), who noted a depression in average daily gain in swine on levels of rapeseed meal from 8% to 15% of the diet. This depression is consistant with observations earlier in this report that young female pigs from 29 kg to 89 kg liveweight grew at a rate of 50 gm less daily when fed rapeseed meal in substitution for soybean meal in their diets. Compared to pigs fed soybean meal, in the starting period average daily gain of pigs fed rapeseed meal was depressed 14% (58 gm daily), in the growing period gain was depressed 9% (66 gm daily, $P < 0.10$), and in the finishing period gain was depressed 9% (81 gm daily, $P < 0.05$).

The offspring of sows fed rapeseed meal gained as rapidly as the offspring of sows fed soybean meal as the main protein source, throughout the period from 6 to 89 kg liveweight. An average daily gain of 674 gm was observed for progeny of sows fed soybean meal as compared to 658 gm daily for progeny of sows fed rapeseed meal, a difference of 16 gm. However, in the starting period (6 to 18 kg liveweight), gain was 40 gm less daily for offspring of R-R sows than for offspring of B-B sows and in the growing period (18 to 55 kg liveweight), 45 gm less. In the finishing period (55 to 89 kg liveweight), 31 gm more daily was

Table 15. Average daily feed, average daily gain, and efficiency of feed utilization -- experiment 2..

Lot	Feeding period	Sex	Rapeseed meal fed to: pigs	Rapeseed meal fed to: dams	No. of pigs	Avg daily feed kg	Avg daily gain gm	Feed/ kg gain kg
1	Starting	F	-	-	4	0.68	385	1.77
2			+	+	4	0.58	298	1.94
3			-	+	4	0.59	337	1.75
4			+	-	4	0.71	389	1.82
1		M	-	-	4	0.77	464	1.65
2			+	+	4	0.64	356	1.80
3			-	+	4	0.70	428	1.64
4			+	-	4	0.69	490	1.40
1	Growing	F	-	-	4	1.81	708	2.56
2			+	+	4	1.57	586	2.67
3			-	+	4	1.76	717	2.47
4			+	-	4	1.88	676	2.77
1		M	-	-	4	2.06	772	2.68
2			+	+	4	1.95	672	2.91
3			-	+	4	2.03	726	2.80
4			+	-	4	2.18	649	3.36
1	Finishing	F	-	-	4	3.12	808	3.85
2			+	+	4	2.76	717	3.84
3			-	+	4	3.10	835	3.71
4			+	-	4	3.08	790	3.89
1		M	-	-	4	3.75	872	4.31
2			+	+	4	3.36	840	4.00
3			-	+	4	3.73	934	4.00
4			+	-	4	3.35	758	4.42
1	Combined	F	-	-	4	1.98	663	3.00
2	Starting		+	+	4	1.79	568	3.14
3	Growing &		-	+	4	1.95	658	2.95
4	Finishing		+	-	4	2.03	645	3.14
1		M	-	-	4	2.30	717	3.20
2			+	+	4	2.06	645	3.21
3			-	+	4	2.16	704	3.08
4			+	-	4	2.24	649	3.45

Table 16. Treatment means for average daily feed, average daily gain and efficiency of feed utilization -- experiment 2.

Feeding period	Factors: Diet for growth	Factors: Dams' diet	Factors: Sex	No. of pigs	Avg daily feed kg	Avg daily gain gm	Feed/ kg gain kg
Starting	SM			16	0.69	404	1.70
	RM			16	0.65	384	1.74
		SM		16	0.71	432	1.66
		RM		16	0.63	355	1.78
			F	16	0.64	352	1.82
			M	16	0.70	435	1.62+
	Mean			32	0.67	394	1.72
Growing	SM			16	1.92	729	2.63
	RM			16	1.90	644+	2.93+
		SM		16	1.98	699	2.84
		RM		16	1.83	673	2.71
			F	16	1.76	669	2.62
			M	16	2.06	703	2.94*
	Mean			32	1.91	686	2.78
Finishing	SM			16	3.42	872	3.97
	RM			16	3.14*	791*	4.04
		SM		16	3.32	816	4.12
		RM		16	3.24	847	3.89
			F	16	3.02	794	3.82
			M	16	3.55*	869*	4.18*
	Mean			32	3.28	832	4.00
Combined Starting, Growing and Finishing	SM			16	2.10	688	3.06
	RM			16	2.03	631*	3.24*
		SM		16	2.14	671	3.20
		RM		16	1.99	658	3.10
			F	16	1.94	648	3.06
			M	16	2.19	634+	3.24
	Mean			32	2.06	685	3.15

+ $P < 0.10$
* $P < 0.05$

gained by offspring of R-R sows. None of these differences were statistically significant. The male pigs gained more rapidly ($P < 0.05$) than the females in the finishing period, and they grew 44 gm daily more rapidly than females throughout the entire period from 6 to 89 kg liveweight.

An F-test (analysis of variance) showed no significant interactions in average daily gain between sex, dam's diet and dietary treatment of progeny. Pigs fed rapeseed meal in their diet at a level of 8% in substitution for soybean meal gained 9.2% more slowly than control pigs fed soybean meal as the main protein source in their diet. Female pigs grew 6.4% more slowly than males. Progeny of sows fed rapeseed meal grew 2.4% more slowly than those of sows fed soybean meal diets.

c) Efficiency of feed utilization

Pigs fed rapeseed meal required 5.9% more feed per kg of gain than pigs fed the basal soybean meal diet. A difference in efficiency of feed utilization measured as kg of feed per kg gain was noted in the growing period (18 to 55 kg liveweight) and in the overall starting, growing and finishing periods at the 10% level of significance. No differences were observed in the starting and finishing periods in efficiency of feed utilization. In contrast, no differences in feed to gain ratios were observed in gilts fed rapeseed meal diets in comparison to those fed soybean meal diets, in experiment 1 discussed earlier in this report. Manns and Bowland (1963a) noted, in agreement with the present results, that efficiency of feed utilization was depressed in the growing period (23 to 50 kg liveweight).

Female pigs were less efficient than males in the starting period ($P < 0.10$) and males were less efficient than females in the growing and finishing periods ($P < 0.05$). No significant interactions were

observed between sex and dietary treatment.

2. Carcass studies

Table 17 lists the lot means and table 18 lists the treatment means for the carcass data. Differences ($P \leq 0.05$) due to feeding of rapeseed meal in substitution for soybean meal were observed in depth of carcass backfat, and in the weight of ham as a percent of the carcass weight. Pigs fed rapeseed meal had an average of 0.33 cm less backfat and a 2.2% greater weight of ham as a percent of carcass than those fed soybean meal diets. Age to market (corrected to 90 kg liveweight) averaged 8 days older for pigs fed rapeseed meal ($P < 0.10$). When carcass R.O.P. score was corrected for age to market by analysis of covariance, pigs fed rapeseed meal had higher scores ($P < 0.10$), a difference of 1.0%. These measures all suggest that pigs fed rapeseed meal had leaner carcasses than those fed soybean meal as the chief source of protein.

Females compared to males had higher R.O.P. scores ($P < 0.01$), less backfat ($P \leq 0.01$), larger loin eye area ($P \leq 0.01$), 5% more lean in the ham face ($P \leq 0.01$), 1.1% more ham as a percent of carcass weight ($P \leq 0.01$), and were 12 days older to market ($P < 0.05$).

The feeding of rapeseed meal to dams of these pigs had no effect on carcass measurements of the market pigs.

The results obtained on the effect of feeding of rapeseed meal on carcass measurements do not agree with those of Seale, 1952 (cited by Bowland, 1965) who stated that rapeseed meal had no effect on R.O.P. score; they vary from those of Hussar (1958), who reported a significant reduction in loin eye area in individually-fed pigs, but not group-fed pigs; and they tend to agree with those of Bell (1965), who showed an increase in loin eye area.

Table 17. Carcass measurements -- experiment 2

Lot		1	2	3	4	1	2	3	4
Diet for growth		SM	RM	SM	RM	SM	RM	SM	RM
Dams' diet		SM	RM	RM	SM	SM	RM	RM	SM
Sex		M	M	M	M	F	F	F	F
Measurement									
Corrected age to market	days	148	153	149	158	158	176	159	162
Dressing %	%	79.2	77.7	77.8	78.8	78.5	78.8	78.2	76.9
Loin eye area	cm^2	24.4	22.2	23.1	23.0	28.8	26.9	26.4	27.8
Lean in ham face	%	45.3	47.8	43.0	43.4	49.7	45.6	48.5	50.9
Carcass length	cm	78.3	79.1	78.8	79.0	79.2	79.5	80.5	79.9
Total backfat[1]	cm	12.0	9.9	10.5	11.0	9.8	8.8	10.3	8.9
Ham/carcass weight	%	26.8	27.3	26.6	27.5	28.3	28.7	27.4	28.1
R.O.P. score		74.9	77.0	75.8	78.8	80.6	80.0	77.6	80.0

[1]Sum of 3 measurements.

Table 18. Treatment means for carcass measurements

		Sex		Diet		Dams' diet		Mean
		M	F	SM	RM	SM	RM	
Corrected age to market	days	152	164*	154	162+	156	159	158
Dressing	%	78.4	78.1	78.4	78.0	78.3	78.1	78.2
Loin eye area	cm^2	23.2	27.5**	25.7	25.0	26.0	24.6	25.4
Lean in ham face	%	44.9	49.7**	46.6	47.9	47.3	47.2	47.3
Carcass length	cm	78.8	79.7	79.1	79.4	79.0	79.6	79.2
Total backfat[1]	cm	10.9	9.4**	10.6	9.6*	10.4	9.9	10.1
Ham/carcass weight	%	27.1	28.1**	27.3	27.9*	27.7	27.5	27.6
R.O.P. score		77.9	79.5**	77.2	78.2+	77.8	77.6	77.7

+$P < 0.10$
*$P < 0.05$
**$P < 0.01$
[1]Sum of 3 measurements.

Table 19. Digestibility and retention studies

		Starter diet				Grower diet			
Lot		1	2	3	4	1	2	3	4
Diet for growth		SM	RM	SM	RM	SM	RM	SM	RM
Diet of dams		SM	RM	RM	SM	SM	RM	RM	SM
Energy									
Digestible	%	86.06	85.29	84.08	84.26	82.83	81.28	82.26	80.48
Metabolizable	%	82.84	82.52	81.36	81.39	79.61	78.52	79.38	77.40
Metabolizable/ digestible	%	96.27	96.76	96.76	96.59	95.87	96.60	96.49	95.66
Nitrogen									
Digestible	%	84.94	82.48	83.40	82.24	83.15	83.44	83.37	82.15
Metabolizable	%	57.07	52.60	53.81	51.66	41.59	44.72	39.99	40.24
Metabolizable/ digestible	%	67.18	63.66	64.40	62.99	50.20	53.45	47.99	48.83

Table 20. Treatment means for digestibility studies

		Factors						
		Age		Diet		Dams' diet		
		Starter	Grower	SM	RM	SM	RM	Mean
Energy								
Digestible	%	84.92	81.71	83.81	82.83	83.41	83.22	83.32
Metabolizable	%	82.03	78.73	80.80	79.96	80.31	80.45	80.39
Metabolizable/ digestible	%	96.60	96.16	96.34	96.40	96.10	96.65	96.38
Nitrogen								
Digestible	%	83.26	83.02	83.72	82.57	83.11	83.17	83.14
Metabolizable	%	53.79	41.63	48.12	47.30	47.64	47.78	47.71
Metabolizable/ digestible	%	64.56	50.12	57.44	57.23	57.30	57.38	57.34

C. Digestibility and Retention of Energy and Nitrogen

Data on the digestibility and retention of energy and nitrogen are presented in table 19 and treatment means are listed in table 20.

1. Starting diets

No significant differences were found in nitrogen and energy digestibility and retention between dietary treatments. Apparent digestibility of nitrogen (DN) of the basal soybean meal starting diet was 84.2% and DN of the equivalent rapeseed meal diet was 82.4%. Since the crude protein content of these diets was 22.7% for the basal diet and 21.5% for the rapeseed meal diet, the contents of digestible protein were 19.1% and 17.7%, respectively.

Coefficients for metabolizable nitrogen (MN) in the starting diets were 55.4% in the basal diet and 52.1% in the rapeseed meal diet. These values varied widely within treatments and the differences between treatments were not significant. In the basal diet, 66.9% of DN was retained and with the rapeseed meal diet, 63.3% of DN was retained.

Apparent digestible energy (DE) was 85.1% for the basal diet and 84.8% for the rapeseed meal diet. The basal diet, therefore, contained 3644 kcal DE/kg and the rapeseed meal diet contained 3609 kcal/kg. ME[1] of the starting diets was 82.1% for the basal diet and 82.0% for the rapeseed meal diet (3517 and 3488 kcal/kg, respectively). ME as a percent of DE was 96.5% and 96.7% for the basal and rapeseed meal diets respectively. Values for ME as a percent of DE varied very little, suggesting that a calculation would give an accurate estimate of ME if DE is known. These values compared quite well with those of Diggs et al (1965) who reported a value of 94.7 kcal ME per kcal DE as an average for various feeds.

[1]Metabolizable energy

2. Growing diets

No significant differences were found for DE, ME, DN, or MN between the growing diets containing soybean meal or rapeseed meal. DN coefficients were 83.3% and 82.8% for the basal and rapeseed meal diets, respectively. MN for the basal diet was 40.8% and for the rapeseed meal diet, 42.5%. Somewhat more nitrogen was retained as a percent from the rapeseed meal diet in the growing period, and more was retained from the soybean meal diet in the starting period, although the same lot of rapeseed meal was being fed in both the starting and growing diets. In the basal diet, 49.0% of the absorbed DN was retained as MN and for the rapeseed meal diet, this value was 51.8%.

DE coefficient of the basal growing diet was 82.5% and that of the rapeseed meal diet was 80.9%. Therefore, the basal diet contained 3254 kcal DE/kg and the rapeseed meal diet contained 3174 kcal DE/kg. Manns and Bowland (1963b) observed a similar non-significant depression in DE in pigs fed 7.8% rapeseed meal. ME values were 79.5% and 78.0%. These coefficients are equivalent to 3155 and 3059 kcal ME per kg. This decrease of 76 kcal ME/kg for a diet with 8% rapeseed meal substituted for 7% soybean meal and 1% wheat indicates a decrease of 940 kcal ME/kg rapeseed meal as compared to soybean meal. This amounts to 36% less ME in the rapeseed meal. Recent observations with chicks (Clandinin and Robblee, 1966) have shown that the metabolizable energy of rapeseed meal was about 1760 kcal per kg, which was about 25% less than that of soybean meal.

GENERAL SUMMARY AND CONCLUSIONS

A. Growth Studies

Rapeseed meal at a level of 8% in diets of growing pigs caused a slight depression in feed intake and in average daily gain and a decrease in efficiency of feed utilization. No deleterious effects were noted in the period from 6 to 18 kg liveweight; a decrease in average daily gain and feed efficiency was observed in the period from 18 to 55 kg liveweight and a decrease in feed consumption as well as average daily gain and efficiency of feed utilization was seen in the period from 55 kg to 89 kg liveweight. After reaching market weight, gilts fed rapeseed meal gained 98 gm less daily in the first month than the controls fed soybean meal diets although feed intake was similar.

Palatability did not appear to be a factor influencing feed intake in these experiments. Putting pigs on a starting diet containing rapeseed meal did not lead to a reduction in feed intake when the pigs had previously been fed diets without rapeseed meal. Changing the diets of 106 kg gilts from soybean meal diets to diets containing 8% rapeseed meal did not lead to an initial decrease in feed intake; but conversely, changing pigs of this weight from rapeseed meal diets to soybean meal diets did result in decreased feed intake.

Feeding rapeseed meal at a level of 8% in the diet adversely affected average daily gain, efficiency of feed utilization and to a limited extent, feed consumption. These effects increased in severity as the pigs approached market weight of 90 kg, and continued to affect female pigs past market weight to breeding. The feeding of rapeseed meal diets to dams did not affect growth characteristics of progeny. Rapeseed meal at a level of 8% in the diet did not appear to make diets less palatable.

B. Reproduction Studies

In the first reproductive cycle, feeding of rapeseed meal for growth of these sows reduced the number of pigs weaned significantly and led to reduced litter weaning weights at a level approaching significance. In the second reproductive cycle, none of the factors measured were affected by a level of 8% rapeseed meal in either the growing or the reproduction diets, and the only effect noted was the failure of two sows to conceive. Breeding weight, gestation gain, changes in sow weight during reproduction, total number of pigs in the litter, litter birth weight, average pig birth weight and average pig weaning weight were not affected by feeding 8% rapeseed meal either during growth or reproduction or both.

A level of 8% rapeseed meal in growing diets of female pigs affected gilt reproductive ability. Number of pigs weaned, as well as litter weaning weight was reduced for sows fed rapeseed meal from 29 to 106 kg liveweight. The latter two observations suggest impairment of sow milk production. Feeding 8% rapeseed meal during gestation and lactation did not significantly influence any reproductive characteristics.

C. Sow Milk Studies

Values obtained for sows' colostrum and milk composition were in agreement with those reported in the literature. Rapeseed meal in the growing diet led to increased levels of fat and consequently total solids in colostrum but did not affect milk composition 1 week after farrowing. Fatty acid levels in the fat of colostrum and milk of sows were not affected by feeding of rapeseed meal.

Dietary rapeseed meal led to an increase in fat levels of sows' colostrum. Levels of solids-not-fat, protein, ash and lactose in colostrum and milk of sows were not affected by a level of 8% rapeseed

meal in the diet. The composition of colostral and milk fat of sows was not altered by feeding rapeseed meal.

D. Carcass Characteristics

The feeding of 8% rapeseed meal to growing and finishing market pigs led to a 2.2% increase in weight of ham as a percent of the carcass weight, a decrease of 0.33 cm in average backfat thickness, an increase of 1.0% in R.O.P. score of the carcass and an increase of 8 days in age of pigs to market. The first two characteristics were significantly different from that of control pigs, and the last two approached significance at the 5% level.

Rapeseed meal as 8% of the diet led to leaner carcasses. This effect was not only due to the fact that pigs fed rapeseed meal were older at market weight.

E. Digestibility Trials

Digestibility and retention of nitrogen, digestibility and retention of energy were not different for either the growing or starting diets when diets containing 8% rapeseed meal were compared to control diets containing isonitrogenous levels of protein based on soybean meal. All these values were slightly, but not significantly lower for the diets containing rapeseed meal.

Substitution of 8% rapeseed meal for 7% soybean meal and 1% wheat did not lower the digestibility or retention of nitrogen, and digestibility or retention of energy of diets of swine from 6 to 55 kg liveweight.

E. Conclusions

A level of 8% rapeseed meal is unsatisfactory for the diets of growing female swine to be used for reproductive purposes. However, this level of rapeseed meal may be used for growing diets of male and female market pigs and for reproduction diets of female swine.

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APPENDIX i

Log retention time vs. carbon number of fatty acids